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ER-WAG7-92INEL-96/185**ENGINEERING DESIGN FILE**

Project/Task Engineering Support of OU 7-13/14
Feasibility Study

Subtask Filling Data Gaps for Processes
and Technologies

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TITLE: Collection of Technology and Process Information for use in the OU 7-13/14 Feasibility Study			
SUMMARY: This EDF contains information on technologies and processes to be used in feasibility study evaluations for OU 7-13/14. Information was collected for the following Remedial Action Alternatives: Institutional Controls & Monitoring Containment In-Situ Treatment Retrieval and Ex Situ Treatment. For technologies and processes that are expected to be selected as representative, more detailed information is found in other documents which are referenced in this EDF. For all other technologies and processes, those expected to be screened out in evaluations or not selected as representative, information in this EDF should provide all that is needed for the feasibility study.			
Distribution (complete package):		C. M. Barnes, K. M. Garcia, D. K. Jorgensen, C. Shapiro	
Distribution (summary page only):		J. J. McCarthy	
Author	Dept.	Reviewed	Date
C. M. Barnes	4170	C. Shapiro	
K. M. Garcia			
Approved		Date	
D. K. Jorgensen		9/6/96	
LITCO Review		Date	
E.M. Barnes 8-19-96		8-22-96	
K.M. Garcia 8-19-96		C. Shapiro	
LITCO Approval		Date	

COLLECTION OF TECHNOLOGY AND PROCESS INFORMATION FOR USE IN THE OU 7-13/14 FEASIBILITY STUDY

Information contained in this Engineering Design File (EDF) was collected for use in the evaluation of technologies, processes and alternatives in the OU 7-13/14 feasibility study. A diagram showing response actions, technologies and processes to be included in the OU 7-13/14 feasibility study is shown in Figure 1. This EDF is intended to contain a complete listing of remedial actions, technologies and processes to be considered in the feasibility study, although minimal information was collected on those not expected to be included in the alternatives evaluation. For a few technologies or remedial actions, more extensive collections of information were collected and are contained in separate documents, and these are referenced in this EDF.

1.0 Remedial Action Alternative 1: No Action

No information is needed at this time in the evaluation of this alternative.

2.0 Remedial Action Alternative 2: Institutional Controls & Monitoring

Institutional controls and monitoring are usually a component of any remedial action. Institutional controls include fences, signs, security personnel activities and legal documents recorded in various county offices, and federal libraries and courthouses. Institutional controls for a site such as OU 7-13/14 are meant to prevent or minimize direct exposure to buried waste or contaminated soil. They do not prevent the transport of contaminants via air, surface water, or infiltration, and hence would be ineffective in preventing migration of contaminants to the aquifer or preventing ecological exposures. Within their limitations they are generally easily implemented and are low cost.

2.1 Access Limitations

Access limitations involve the prevention of access by unauthorized personnel. Security personnel at entrance gates can be used, but expense generally limits the use of security personnel to the period of remediation. According to 10 CFR 60 & 61 the institutional control alternative can assume that if people are made aware of the danger of access, they will choose not to enter the waste area. Thus the access limitation system is designed to prevent inadvertent intrusion such as exploratory drilling, but there is no requirement to attempt to prevent deliberate intrusion. It is assumed that access limitations to prevent inadvertent intrusion to the waste site will include a marker system.

Figure 1. OU 7-13/14 Feasibility Study Response Actions, Technologies and Process Options,

<u>General Response Action</u>	<u>Technologies</u>	<u>Process Options</u>
1. No Action	Earthen Cover	Existing Cover
2. Institutional Controls	Access Limitations	Legal Restrictions Physical Barriers and Markers
	Monitoring ¹	Groundwater & Soil Monitoring
3. Containment ²	Below Grade Isolation	<i>Vertical Barriers</i> <i>Slurry Walls</i> <i>Sheet Piles</i> <i>Grout Curtains</i> <i>Freeze Walls</i> <i>Horizontal Barriers</i>
	Capping	Water Balanced System RCRA Composite
4. In-Situ Treatment	<i>Physical or Chemical Stabilization</i>	
	Thermal Stabilization	Vitrification
	<i>Soil Flushing</i>	
	<i>Electrokinetics</i>	
	<i>In Situ Bioremediation</i>	
5. Retrieval and Ex Situ Treatment	Retrieval/Containment	Small Mobile Building Large Building with Foundation
	<i>Ex Situ Bioremediation</i>	
	Physical Separation	Pretreatment Separation (Pit 9) Waste Type Sorting Segmented Gate Process Soil Wash Physical Decontamination

Table 1. OU 7-13/14 Feasibility Study Response Actions, Technologies and Process Options, (Continued)

<u>General Response Action</u>	<u>Technologies</u>	<u>Process Options</u>
5. Retrieval and Ex Situ Treatment (Continued)	Chemical Separation	Chemical extraction/phase separation/concentration Chemical Decontamination
	<i>Thermal Oxidation</i>	
	Stabilization/ Solidification	Vitrification/Melting Plasma Arc Centrif. Treatment Graphite Electrode Melter Plasma Hearth Melter Microwave Melter Fossil Fuel Cyclone Furnace Cementation/Inorganic Processes Hydraulic Cements Pozzolanic Processes Aquaset/Petroset Phosphate Ceramics Polymer Processes Sulfur Polymer Cements Bitumen Polyethylene Thermosetting Polymers Macroencapsulation Amalgamation Tritium Stabilization ¹⁴ CO ₂ Stabilization
	Storage	
	Disposal	WIPP Other offsite Onsite

Technologies and Process Options Screened Out
Representative Process for Detailed Evaluation

Notes on Figure 1

- ¹ Monitoring will be included in all response actions.
 - ² All containment technologies are assumed to also include a means for flood and erosion control.
 - ³ Support technologies such as drilling, VVE, offgas treatment, and process chemical recovery may be required for some of the technologies listed.
 - ⁴ Response actions 5 and 6 require multiple technologies selected from those listed.
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Principles that guide the creation of a marker system are (1) the site must be marked, (2) messages must be truthful, (3) use of multiple components within a system, (4) use of multiple means of communication, e.g. language, pictographs, scientific diagrams, (5) multiple levels of complexity within individual components of the system, (6) use of materials with little recycle value - unevenly shaped, natural materials, (7) an international effort to maintain knowledge of the location and contents of nuclear waste repositories.

Probability studies show that after 500 years the survivability and usefulness of any marker system decreases¹. While the survivability of the physical marker was still at a 40% probability the issue of understanding the message drops to a 1% to 30% probability. Though facial expressions and pictographs would also be used, language would be most important. The use of several different languages doesn't account for the creation of an entirely new language not based on any of the languages of the marker system. This issue has not been resolved so that a conceptual design can proceed for WIPP. Based on the current development status of the concept it does not seem feasible that markers would be would offer sufficient long term protection from intrusion.

Land use restrictions include zoning and deed restrictions. Deed restrictions involve specific limitations on future land use that are incorporated in the deed of ownership to a particular property. Examples of deed restrictions would be to prohibit residential or agricultural use, to restrict excavation, to prohibit drilling for minerals or water, or to maintain the integrity of a surface barrier.

2.2 Monitoring

No information was collected on monitoring technologies at this time. Monitoring will be a component of every remediation alternative, with different requirements for different alternatives.

3.0 Remedial Action Alternative 3: Containment

3.1 Capping

Capping is retained for inclusion in the alternatives evaluation. Information to be used to evaluate capping for remediation of OU 7-13/14 has been collected and documented in *Summary of Technical Issues for Cap Designs for the SDA*, INEL-96/0033. This report includes information from several demonstration projects occurring at Hanford and the INEL.

3.2 Below Grade Isolation

Below grade isolation has been considered as a subcomponent of both capping designs. It is assumed that any isolation barrier will be required to have a service life of 1000 years. This capability may be demonstrated through the use of natural analogs and accelerated tests. Barriers that are not expected to be able to be protective for such a long life cycle are slurry walls, sheet piles, grout curtains, and freeze walls. These alternatives are thus not retained for further evaluation.

4.0 Remedial Action Alternative 4: In Situ Treatment

4.1 Physical Or Chemical Stabilization

Physical and chemical stabilization are not retained for inclusion in the alternatives evaluation. Full-scale experimental investigations have been done at the INEL and have been reported in several papers (see Loomis, *Innovative Subsurface Stabilization of Transuranic Pits and Trenches*, INEL-95/0632, Dec. 1995). This alternative is suitable for interim actions requiring stabilization of hot spots or the creation of temporary vertical walls for structural stability. Natural analog studies have yet to conclude what parameters are crucial for predicting long term durability.¹ Until these parameters are identified the long-term life cycles of any in-situ stabilization method can not be evaluated.

4.2 Vitrification

Vitrification is retained for inclusion in the alternatives evaluation. Information to be used to evaluate in situ vitrification for remediation of OU 7-13/14 has been collected and documented in Engineering Design File ER-WAG7-95, INEL-95/319, "Digest of Reports and Information on Status of In Situ Vitrification Technology." The EDF includes information from ISV tests and demonstration projects, cost estimates, and discussions and assessments of the applicability of the technology to treat the buried waste of OU 7-13/14. All information included in the EDF is based on the Geosafe in situ vitrification (ISV) process.

Alternate forms of ISV technology are being developed based on a "bottoms-up" approach rather than the conventional melting from the top down. In this approach, a heat source is lowered into a borehole, and progressively raised as the waste and soil around it is melted. Development is ongoing for two variations of this approach, one which uses a concentric graphite arc melter and the other a plasma torch for the heat source. Information regarding this approach is contained in:

1. P. S. Lowery, J. Luey, D. K. Seiler, J. S. Tixier, *Depth Enhancement Techniques for the In Situ Vitrification Process*, PNL-SA-24899, November, 1994.
2. S. A. Bogatov, A. A. Borovoi, S. L. Camacho, "PRISM - Plasma Remediation of In-Situ Materials and its Potential for the Remediation of Chernobyl Consequences," *Proceedings of the International Symposium on Environmental Technologies: Plasma Systems and Applications, Atlanta, Georgia, October 8-11, 1995*, pp. 631-638.
3. J. Luey, D. K. Seiler, *Application of In Situ Vitrification in the Soil Subsurface: Engineering-Scale Testing*, PNL-10485, March, 1995.
4. Montec Associates, *In Situ Waste Destruction and Vitrification Process for the Remediation of Hazardous and Mixed Wastes, Project Synopsis*, July, 1995 (Confidential proprietary information).
5. L. C. Farrar, Montec Associates, Personal Communication to C. M. Barnes, September 18, 1995.
6. L. J. Circeo, Jr., G. K. Jacobs, S. L. Camacho, N. C. Raleigh, J. S. Tixier, *The PRISM Concept*, CONF-941124-8, 1994

4.3 Soil Flushing

Soil flushing is an in situ process that uses an injected fluid to mobilize and transport contaminants to a collection and treatment system. The fluid is typically water or water containing additives selected to dissolve, desorb, or react with contaminants in the soil, although gaseous fluids such as steam or carbon dioxide are also used. The technology has been practiced commercially for more than 50 years in the oil and gas industry and for several decades in the mining industry but only recently adapted for application to hazardous waste. Applications have primarily been for removal of hydrocarbons including VOCs, SVOCs, PAHs. Mining industry experience is limited to a few metals, notably uranium and copper.

Soil flushing would not be effective for OU 7-13/14, and is not retained. The heterogeneity of the buried waste and soil precludes uniform flow through the soil/waste medium. Containers, even if corroded or breached, would divert the elutriate fluid around pockets of waste. Rather than remove contaminants, in-situ soil flushing may result in increased migration of COCs to the aquifer, due to the volumes of fluid injected during soil flushing. Construction of a system that ensures total recovery of the elutriate would be essentially equivalent to a total retrieval effort. Also, the high clay and fines content of the OU 7-13/14 soils, being in an unsaturated zone, may readsorb COCs or retain large amounts of the contaminant-laden fluid, which, in future years following remediation, could migrate to the aquifer. In addition, it is very doubtful that a fluid could be found that would remove all the different COCs and all of the chemical forms of specific COCs in the OU 7-13/14 soil and waste.

4.4 Electrokinetics

Electrokinetic soil processing is an in situ remediation technique that involves the transport of contaminants by applying an electric field between electrodes inserted into the soil. Natural moisture or an externally supplied fluid provides the conductive medium, and an open flow arrangement at the electrodes allows the processing or pore fluid to flow between soil and electrode. Electrolysis reactions at the electrodes and cycling the processing fluid result in transport through the porous soil by conduction phenomena in soils under electric fields. Extraction and removal are accomplished by electrodeposition, precipitation, or ion exchange either at the electrodes or in an external treatment system processing the circulating fluid. The efficiency of an electrokinetic process is related to the ionic mobility and concentration of the contaminants of concern, as well as other interfering species present in the soil.

Electrokinetic processing is potentially applicable to heavy metals, radionuclides, and organic contaminants. Bench-scale tests have shown removal efficiencies of 75-95% for lead, chromium, cadmium and uranium, at levels up to 2000 $\mu\text{g/g}$.²

Because of the great quantities of containerized waste present in OU 7-13/14, electrokinetics would not be effective. Even if a pretreatment step was used to perforate all containers, the metal drums and the heterogeneity of the waste would seriously limit the effectiveness of the process because of barriers to flow of fluids as well as electric current. It is also questionable whether all of the COCs present in OU 7-13/14 could be dissolved by and removed to the required remediation levels by an electrokinetic process. For these reasons, this technology is not retained.

4.5 Bioremediation

Bioremediation is the use of microorganisms to degrade, mineralize, mobilize, immobilize, extract or otherwise transform hazardous substances into innocuous materials.

In-situ remediation has been successfully applied to sites contaminated with hazardous organics. Microorganisms are also known to degrade mineral compounds and bioleaching has been used to mine such metals as uranium, copper and gold.

However, for the radionuclide contaminants of OU 7-13/14, bioremediation is not expected to be effective and may cause adverse effects to the environment. The containerized waste would prevent even flow of organisms, moisture, and nutrients to the waste, resulting in large amounts of untreated waste. The widely diverse waste matrix types, contaminants, and contaminant chemical forms also hinder the effectiveness of bioremediation, with some contaminants toxic to the microorganisms, and others highly insoluble in water. Large amounts of water would need to be added to the site to promote microbial activity and transport microorganisms and nutrients to waste, yet this water may promote transport of contaminants into the basalt underlying the SDA and ultimately into the aquifer. Bioremediation processes that leach metals would need to be combined with a soil flushing process, which has been screened out. Thus in situ bioremediation is not retained for further consideration in the OU 7-13/14 feasibility study.

5.0 Remedial Action Alternative 5: Retrieval, Ex Situ Treatment, Storage and Disposal

5.1 Retrieval

Retrieval is retained for the alternatives evaluation. Successful demonstration of remote retrieval feasibility has been done three projects:

- a) Waste from a cold test pit (D. J. Valentich, *Full Scale Retrieval of Simulated Buried Transuranic Waste*, EGG-WTD-10895, September, 1993),
- b) Overburden from a cold test pit (P. Rice, *Removal of Overburden Soils from Buried Waste Sites*, EGG-WTD-10767, October, 1993), and
- c) Waste from a cold test pit (A. M. Smith, *An Integrated Systems Approach to Remote Retrieval of Buried TRU Waste*, INEL-94/0123, February, 1995).

Demonstrations did not include testing of control of airborne contaminants, mobility of the containment building, assay nor criticality monitoring. All of these design elements are considered essential to the implementability of a retrieval alternative. Further data are needed for the evaluation. Criticality monitoring needs to include measurement of the activity at the location and spectra data or neutron monitoring. The containment building design will be tested for its ability to maintain a seal between the foundation and the waste zone, and to contain any airborne emissions. The Pit 9 retrieval design evaluation and possible alternatives can be found in EDF ER-WAG7-91, *Evaluation of Pit 9 Treatment System for Remediation of OU 7-13/14*.

5.2 Physical Separation

Pretreatment separation can be done according to many parameters such as size, weight, moisture content and hardness. The extent to which separation is done at all must always be balanced against the cost of measurement, volume reduction, and treatment costs. There is a point where it is more efficient to send an entire waste stream to treatment than to increase the complexity of the system. Many commercial systems exist for shredding and sorting but implementability and cost must always include the measurement and assay components. A review of shredding technologies can be found in N. R. Soelberg and G. A. Reimann, *Radioactive Waste Shredding: Preliminary Evaluation*, EGG-MS-11147, July, 1994.

Retrieval and treatment rates can be impacted by the time to measure and verify the separation. Studies show that soils with a high percentage of sand benefit from centrifugal and jig separation with radioactive contaminants staying with the finer soil particles. But the SDA soils are known not to have a large volume of sand and loose rocks, thus, little volume reduction would be expected. Initial separation of soil from waste forms will occur in the Pit 9 process by using a soil brush during retrieval. Sizing of bulk objects can also be done with shears during the retrieval operation. Once cut or disassembled to smaller sizes, metal objects can be put into separate boxes and sent for surface decontamination.

Soil separation may also occur using a series of assay steps such as in the segmented gate process. Soils are placed on a conveyer and passed by radiation detectors which control the sorting of the soil into clean volumes or contaminated volumes. This has shown to reduce the soil volume by 98%³ leading to a significant cost savings.

Metal objects could be placed separately from boxes, sludges, and soils. Initial assay of metals or assay after a surface decontamination could allow for shipment of metals to a separate metal recovery treatment offsite where 95% recovery has been achieved (F. Nichols, Manufacturing Sciences Corp literature). If 30% of the waste volume is metals this could lead to a significant volume reduction. The cost of shipping and handling will need to be collected and evaluated for the process.

Physical decontamination involves either surface cleaning methods or mechanical substrate surface removal. Surface cleaning methods include blasting with solid CO₂ pellets, high pressure water, superheated water, or steam and ultrasonic cleaning. All of these methods are commercially available and have been used in nuclear applications. CO₂ pellet blasting minimizes waste by having no liquid effluent, while the other methods require a system to treat the resultant decon solution.

Mechanical substrate surface removal methods are typically used when more aggressive cleaning is needed, and include blasting with sand, shot, ice, plastic pellets, ultra-high-pressure water (up to 55,000 psi), or solid nitrogen, scarifying, grinding and high-pressure jet spalling. These processes have all been demonstrated and could be used at a specific

location at the SDA where metals and large objects could be brought from the retrieval site, and then sent on for assay. The cost effectiveness of this step depends on the type of contamination expected in the metals, and whether the decontamination is from activated products or corrosion products. The particular process used will depend on whether a separate system will be needed to treat decon effluents, the type of decontamination, and the type of substrate materials. To handle the different waste types and forms, more than one decontamination process may be needed.

5.3 Chemical Separation

Chemical separation technologies generally include several unit operations such as extraction, ion exchange, phase separation, adsorption and precipitation. Thermal separation unit operations such as evaporation or catalytic oxidation are often integrated into a chemical separation technology to recover solvent, or concentrate or destroy extracted contaminants. Physical separation techniques are often used as pretreatment steps to a chemical separation process to reduce the volume of material to be treated by chemical separation.

5.3.1 Chemical Extraction

Chemical extraction technologies, sometimes also called chemical soil wash or leach processes, use solvents to extract contaminants from soil, sludges, or solid waste. Solvents used in chemical extraction technologies include water, acids, bases, organic liquids, chelants or complexing agents, supercritical fluids, and soil polymers. Additives, such as inorganic salts or oxidants are sometimes used. The extractions may be carried out in multiple stages or steps, and different solvents may be used in different steps. Most chemical extraction processes will include steps to concentrate the contaminants removed from the waste and recover the solvent for recycle.

Chemical extraction processes are usually site-specific designs because of differences in contaminant species, contaminant chemical forms, matrix (soil or waste) properties, and cleanup level specifications. For sites as complex as OU 7-13/14, treatability studies and pilot testing are required to optimize operating parameters and confirm or determine performance. Because of the data available for the Pit 9 chemical extraction process, it will be used in the OU 7-13/14 Feasibility Study as representative of chemical extraction processes. However, there are very few alternative extraction processes that hold any potential for achieving the remediation goals of OU 7-13/14. Extraction processes based on water or weak acids would not adequately remove the transuranic or other metal COCs. Processes which use contaminant-specific additives are likely to require sequential extractions and have high costs.

The Pit 9 process uses two extraction processes to remove organics and transuranics from Pit 9 soil, plus a third extraction to remove calcium carbonate. Organics are extracted with triethylamine and transuranics with nitric acid enhanced with Ce^{+4} ions. To reduce the consumption of nitric acid, calcium, present in the soil as calcium carbonate, is extracted

with water. The Pit 9 chemical extraction process is discussed in more detail in EDF ER-WAG7-93, INEL-96/186, *Information for Evaluation of Pit 9 Chemical Treatment System Applied to OU 7-13/14*.

There are several extraction process alternatives to the nitric acid-based process of Pit 9, but few have significant full-scale or even pilot scale experience with radioactive contaminants. The process type with the most experience, referred to by trade names ACT*DE*CON or CACITOX, uses a solvent mixture of water, carbonate or bicarbonate, oxidant and chelant or complexant. A proof of principle (POP) test was performed using this process for simulated Pit 9 waste. Compared to the Pit 9 extraction steps, this process has the potential advantages of extracting organic and inorganic contaminants in one rather than two steps, and treating waste forms such as sludges as well as contaminated soil. However, test data would be needed to adequately determine effectiveness and implementability of this process for application to SDA wastes and scale of operation.

5.3.2 Phase Separation/Concentration

If contaminants are extracted from soil or solid waste into a liquid, additional unit operations are needed to concentrate the contaminants or separate from the liquid solvent, thus permitting recycle of solvent and resulting in a low volume of contaminant containing waste to be disposed of. Separation and concentration unit operations fall both under the categories of chemical treatment and thermal treatment. Because of their widespread use in both water treatment and the chemical process industries, most of these processes are well known and commercially available.

Most extraction processes utilize phase separation to recover solvent from the soil/solvent slurry, to separate contaminants from solvents, or separate recovered liquids such as oils or water from the extraction solvent. Common and well established phase separation methods include gravity separation, air flotation, centrifuging, screening, filtering, evaporation, drying and distillation. Steam and air stripping are additional common liquid purification techniques based on multistage mass transfer between phases.

Ion exchangers, containing beds of ion exchange resins, are used to remove dissolved ions from liquid streams. Ion exchange is a well established technology for removal of radionuclides, some hazardous metal ions, and other inorganic ions such as fluoride or nitrate. A potential problem for treatment of soil extractants is to find one sufficiently selective for COCs, yet robust for the range of concentrations of competitive ions expected in the solution. Ion exchangers need to either be regenerated, which results in another liquid waste that requires treatment, or the resin disposed of, that adds expense both for replacement resin and disposal.

Carbon adsorption is a well established process for removal of organic contaminants from liquid or gaseous streams. Specially treated activated carbon can also remove some metals, such as mercury, from wastes streams. Like ion exchangers, carbon adsorption beds require either regeneration, further processing, or disposal.

Precipitation involves the addition of one or more chemicals to the extraction liquid to cause a chemical reaction with dissolved contaminant species, forming solids that can then be separated by conventional solid/liquid separation techniques. Precipitation chemicals can be inorganic materials such as lime or sulfides, organic compounds, or polymers. Additives to control oxidation states or pH are often needed in precipitation.

Membrane separation processes, including reverse osmosis, microfiltration, ultrafiltration, dialysis, electrodialysis, pervaporation, and liquid membrane separation can be used to separate liquids or specific ions from liquid streams. While some processes and applications are developmental, membrane processes have seen a growing application in wastewater treatment in a variety of industries. The applicability to remediation of OU 7-13/14 will depend on the type of solvents used in extraction and the conditions used in the extractions. Harsh conditions, such as low pH or high temperature, cause rapid degradation of many membranes.

5.3.3 Chemical Decontamination

Chemical decontamination involves the use of chemical agents to loosen, solubilize and remove surface contamination. Contact may be achieved by immersion of the contaminated object in a chemical bath or by surface application of the chemical as a liquid, foam, or gel. Chemical agents that are most commonly used include aqueous solutions of mineral or organic acids, chelating agents, caustic, organic solvents, and detergents. Chemical decontamination is often used in conjunction with a mechanical process such as scrubbing, grinding or ultrasonic cleaning.

Many chemical decontamination agents are well established because of use in the nuclear industry, including nitric acid, hydrochloric acid, phosphoric acid, oxalic acid, caustic and detergents, and hence these systems would be easily implementable. Generally organic solvents and detergents are used to remove grease, dirt, and organic contaminants, acids and alkalis remove oxide films, and complexing agents solubilize certain ions. The multiple types of contaminated materials and contaminants present in the pits and trenches may require multiple decontamination methods, as decontamination effectiveness varies both with surface type and contaminate. Use of chemical decontamination agents compatible with the chemical treatment system would avoid the need for a separate system to process spent decontamination solutions.

5.4 Stabilization/Solidification

Of the different solidification technologies, only vitrification and melting technologies have the potential for producing products that are expected to be nonleachable or stable over the thousands of years needed for long-lived radionuclides. Vitrification/melting has the added advantages over other solidification systems of resulting in a volume decrease and being able to process more highly variable and diverse waste types. Thus vitrification/melting is selected as the representative technology for the ex situ treatment alternative.

However, vitrification/melting technologies cannot incorporate certain contaminants that are volatile at the melt temperature, and thus other stabilization technologies are retained for inclusion in the feasibility study. Any ex situ treatment system will thus likely require more than one stabilization process. The Pit 9 process uses two stabilization processes, vitrification to immobilize transuranic elements and hazardous metals, and a cementation process to solidify melter offgas treatment scrubber blowdown wastes, which contain radionuclides and hazardous metals that are incompletely incorporated into the furnace slag. An OU 7-13/14 ex situ treatment system may require additional stabilization/solidification systems for tritium- and C-14-contaminated streams and possibly for bulk lead or mercury wastes.

5.4.1 Vitrification/Melting

In the OU 7-13/14 feasibility study, vitrification will be represented by the Pit 9 plasma melter which is a centrifugal, plasma-torch furnace manufactured by Retech. Information for the Pit 9 melter is contained in EDF ER-WAG7-87, INEL-95/023, *Index and Discussion of Data Gathered for the Plasma Arc Centrifugal Furnace*. Until the LPT results are available in order to assess the Pit 9 plasma furnace, no other melter designs will be considered in the feasibility study.

However, if needed, a considerable amount of information is available on other melter designs, including test data for surrogate INEL buried waste. Data for, and evaluations of graphite electrode melters for INEL buried waste are contained in:

1. N. R. Soelberg, J. F. Keck, D. D. Taylor, G. L. Anderson, *Graphite Electrode Arc Melter Demonstration: Technology Evaluation*, INEL -95/0493, (unpublished draft), September, 1995
2. N. R. Soelberg, A. G. Chambers, G. L. Anderson, W. K. O'Connor, L. L. Oden, P. C. Turner, *Graphite Electrode Arc Melter Demonstration Phase 2 Test Results*, INEL-95/0502, (draft) April, 1996.
3. N. R. Soelberg, A. G. Chambers, G. L. Anderson, *Arc Melter Vitrification of Organic and Chloride Containing Materials*, INEL-95/393, 1995.

4. N. R. Soelberg, A. G. Chambers, L. Ball, *Vitrification of Surrogate Mixed Wastes in a Graphite Electrode Arc Melter*, INEL-95/269, 1995.
5. L. L. Oden, W. K. O'Connor, P. C. Turner, N. R. Soelberg, G. L. Anderson, *Baseline Tests for Arc Melter Vitrification of INEL Buried Wastes, Volumes I and II*, EGG-WTD-10981, November, 1993.
6. N. R. Soelberg, A. G. Chambers, G. L. Anderson, L. L. Oden, W. K. O'Connor, P. C. Turner, *Arc Melter Demonstration Baseline Test Results*, EGG-WTD-11138, July, 1994.
7. J. E. Suma, C. J. Freeman, T. D. Powell, R. A. Hamilton, D. L. Smatlak, P. Thomas, C. H. Titus, J. K. Wittle, P. P. Woskov, *Evaluation of the Graphite Electrode DC Arc Furnace for the Treatment of INEL Buried Wastes*, PNL-8525 UC-602, 1993.

Evaluation data for the plasma hearth melter is contained in:

1. R. L. Gillins, R. M. Geimer, *Plasma Hearth Process Vitrification of DOE Mixed Waste*, INEL-95/321, 1995.
2. R. Geimer, C. Dwight, G. McClellan, *The Plasma Hearth Process Demonstration Project for Mixed Waste Treatment*, ANL/TD/CP-83149, 1994.
3. M. Aycock, D. Coordes, J. Russell, W. TenBrook, P. Yimbo, *Preliminary Hazards Analysis Plasma Hearth Process*, DOE/MWIP-13, November, 1993.
4. J. M. Chiang, W. D. Bostick, D. P. Hoffman, W. H. Hermes, L. V. Gibson, Jr., A. A. Richmond, *Surrogate Formulations for Thermal Treatment of Low-Level Mixed Waste; Part 3: Plasma Hearth Process Testing*, DOE/MWIP-17, January, 1994.

Reviews of melter technologies, either general or specific to INEL buried waste, are contained in:

1. T. L. Eddy, B. D. Raivo, N. R. Soelberg, O. Wiersholm, *Advanced Mixed Waste Treatment Project Melter System Preliminary Design Technical Review Meeting*, INEL-95/54, February, 1995.
2. J. A. Jones, *Vitrification Melter Study*, DOE/ID-10515, April, 1995
3. L. J. Staley, "Vitrification Technologies for the Treatment of Contaminated Soil," *Emerging Technologies in Hazardous Waste Management V, ACS Symposium Series* 607, 1995, pp. 102-134.

4. R. Gillins, G. L. Anderson, *An Assessment of Incineration and Melting Treatment Technologies for Application to RWMC Buried Waste*, EGG-WTD-10035, February, 1992.
5. H. Zaghoul, R. Cortez, E. Smith, "Plasma Waste Remediation Activities in the United States," *Proceedings of the International Symposium on Environmental Technologies: Plasma Systems and Applications, October 8-11, 1995, Atlanta, Georgia*, pp. 1-12.

A preliminary review of cyclone furnaces applied to OU 7-13/14 is contained in Section 3.4.4 of:

C. M. Barnes, K. Garcia, J. Prendergast, *Preliminary Development of Alternative Remediation Technologies and Identification of Data Needs for OU 7-13/14 Feasibility Study*, Engineering Design File ER-WAG7-78, INEL-95/199, Revision 1, September 9, 1995.

Information for 10 commercial ex-situ vitrification systems can be found in EPA's VISITT 4.0 database. Several of these commercial vitrification systems are fossil-fired melters, while at least one plasma melter, DE arc, and microwave system is included. Microwave melting has been developed both in Japan⁴ and at DOE laboratories^{4,8} for in-drum melting of radioactive waste. A full-scale microwave unit has been demonstrated using Rocky Flats sludges, and design of a production unit for Rocky Flats is in progress.⁸

5.4.2 Cementation and Inorganic Solidification Processes

Cementation processes include the use of hydraulic cements, pozzolanic cements, and other inorganic solidification agents such as the commercial products Aquaset and Petroset. Also included are other inorganic solidification processes such as chemically bonded phosphate ceramics.

Hydraulic cements consist primarily of calcium silicates and calcium aluminates, with smaller quantities of other oxides and additives. When the cement powder is mixed with water or an aqueous waste, hydration occurs and the cement hardens. As the cement begins to harden or cure, a colloidal gel of indefinite composition and structure is formed. Over time, the gel swells and forms a matrix composed of interlacing, thin, densely packed silicate fibrils. Constituents present in a waste slurry are incorporated into the interstices of the cement matrix.

The mechanism and chemistry of cement hardening is complex, and poorly understood, even for relatively simple cements as Portland cement.⁹ Many ions are known to interfere with the solidification process or be difficult to stabilize.⁹ These include borates, tri-basic phosphate, volatile organics, and mercury.^{10, 11} Additives or low loadings may be required for ammonium salts, arsenates, chlorides, copper compounds, heavy metal salts, lead

compounds, magnesium compounds, phosphates, spent resins, sodium compounds, sulfates, tin compounds and zinc compounds.^{10, 11} The specific effect of these interfering ions is dependent on their concentration, the associated anions and cations in the waste, the composition of the cement and additives, and the ratio of waste to cement.

While it has been reported that "nearly any waste stream can be, and has been, successfully stabilized with Portland cement,"¹² there are many cases where specific wastes were very difficult to solidify with hydraulic cement and required extensive test programs to obtain an adequate formulation. Cement has an open cell structure that becomes porous as it cures, which in turn can allow water to permeate and leach contaminants. Thus use of hydraulic cement would not be feasible nor effective for all the diverse wastes of OU 7-13/14 with largely unknown compositions, although it may be acceptable for specific secondary wastes from a chemical treatment system.

Pozzolan processes, also referred to as silicate-based or lime-based solidification, use a pozzolan material such as fly ash plus hydrated lime to immobilize a waste stream. Pozzolan materials are also often used as additives to hydraulic cements. Solidification of pozzolan materials is similar to cement, but usually slower. Like cement processes, many ions can interfere with the lime-pozzolan reactions and some hazardous metals can be difficult to immobilize.

The Pit 9 plasma melter offgas scrubber blowdown waste, after evaporation, will be solidified with Aquaset/Petroset, commercial products of Fluid Tech, Inc. (FTI). There are actually six Aquaset/Petroset products, that are used singly or in combination for different waste types, some of which produce a flexible clay product rather than hard concrete. The Aquaset/Petroset products are primarily Montmorillonite clays or mixtures of clays and cement. For aqueous wastes with high ionic concentrations, such as the scrubber blowdown, the manufacturer's literature¹³ recommends Aquaset II, and the use of 125-175 lbs of the stabilization product to 43-47 gallons of waste. This is equivalent to a waste loading of 67-76%, a considerably higher loading than can be achieved with cement products.

Performance reports supplied by FTI give leachability indexes and TCLP results for several radionuclides (Sr-85, Cs-137, and Co-60) and for RCRA-hazardous metals for a variety of wastes, although insufficient information about the waste composition to compare with expected Pit 9 sludge composition. Treatability studies using Aquaset and Petroset have been performed for 51 waste streams, encompassing a wide compositional variation and numerous radionuclides.¹⁴ In a few cases where high loadings were used, the product did not set up or did not pass the Paint Filter Liquids Test. The study concluded that Aquaset II and Aquaset II-H worked well for all aqueous waste except neutralized concentrated sulfuric acid.

Low-temperature-setting phosphate ceramics have been proposed for stabilization of certain DOE mixed wastes which cannot be treated by high-temperature processes.¹⁵ Phosphate cements are commercially available and have been applied to heavy-metal-containing wastes.^{16,17}

5.4.3 Polymer Processes

Polymer solidification processes include bitumen, polyethylene and sulfur cement, all thermoplastic polymers, and epoxy and vinyl ester polymers which are thermoplastic polymers. These organic binders contain the waste material by microencapsulation. The waste is surrounded, immobilized and isolated from the environment by the highly impervious network structure of polymers. Processing techniques for polymer processes are well established in the plastics industry, and typically include extruders, mixers or both.

Bitumen is a complex mixture of high molecular weight hydrocarbons which are residues of petroleum and coal-tar refining processes. Bitumen has two major components - asphaltene compounds, which give it colloidal properties, and malthene compounds, which impart viscous liquid properties. Unlike hydraulic cements, no chemical bonding of waste takes place in bitumen, instead the stabilization agent physically entraps the waste particles. If water or volatile liquids are present in the waste, they are evaporated prior to or within the bitumen stabilization process, and must be further treated. Bitumen solidification processes typically operate at temperatures greater than 150°C. Bitumen is commercially available, has been widely used in Europe to stabilize radioactive waste, is compatible with a wide range of wastes, and is relatively low-cost. However, the flammability gives rise to safety concerns; it is incompatible with certain waste components such as nitrates, and radiological decomposition may be a concern for some wastes.

Sulfur polymer cement (SPC) is composed of approximately 95% sulfur, 2.5% dicyclopentadiene and 2.5% oligomers of dicyclopentadiene.¹⁸ Waste loadings are considerable higher for most waste types, in part because no water is needed in the SPC process. SPC is used commercially in the construction industry, and is available under the trade name Chement 2000. SPC is a thermoplastic ceramic that starts softening at 110-115°C and reaches an optimum pour consistency at 135°C. It is nonflammable, non-biodegradable, has high strength and low permeability, and is resistant to abrasion and attack by most acids and salts.¹⁸ Solidification of SPC is reversible by heating, and will regain its strength upon recooling.

SPC has been developed for hazardous, radioactive, and mixed waste applications. SPC is not recommended for sodium nitrate salts, wastes above 100°C, organic wastes, highly soluble compounds, ion-exchange wastes or wastes with a pH greater than 8-10,¹⁸⁻²⁰ but could be applied to high concentrations of mineral acids, corrosive electrolytes, salt solutions problematic for other solidification methods, and wastes containing hazardous metals volatilized in a high temperature process.¹⁹ An SPC process would require an offgas system, feed wastes need to be heated to at least 200°C prior to incorporation in SPC, and disposal containers need to be preheated.^{19,20}

Other thermoplastic polymers used for solidification include polyethylene, polyvinyl chloride and polymethyl methacrylate. Of these, polyethylene has seen the most development for application to DOE mixed waste, and has been studied for application to Rocky Flats

nitrate sludge,^{21,22} salt residues generated from molten salt oxidation processing,²³ INEL eutectic salts,²⁴ INEL spent ion exchange resins,²⁴ activated carbon,²⁴ freon contaminated rags,²⁴ ICPP sodium bearing liquid waste,²⁴ lead and mercury contaminated acid spill cleanup waste,²⁴ blowdown waste from the Consolidated Incinerator Facility at Savannah River,²⁵ and Hanford solid and sludge wastes from planned liquid effluent treatment facilities.²⁶ Results have been mixed for these treatability studies. In some cases, TCLP results have shown concentrations higher than regulatory limits, indicating the need for reduced loading or additional development. Most of these tests have been performed with wastes loadings greater than 50%. Like other thermoplastic waste processes, polyethylene solidification requires pretreatment to remove water, in some cases even water of hydration, to typically less than 2%.²⁴ Relatively small particles, less than 2 mm, and uniform particle size is also required.²⁴

In contrast to thermoplastic polymers that solidify upon cooling and involve no chemical reactions, thermosetting polymers require catalysts or promoters to initiate polymerization and solidification. And because chemical reactions are involved, waste constituents can interfere with the polymerization. Properties of the solidified product, and waste loadings, are generally similar for thermosetting and thermoplastic polymers. Thermosetting binders include vinyl ester styrene, polystyrene, epoxy and polyurethanes. Vinyl ester styrene (VES) is capable of immobilizing free water in the polymer matrix, while epoxies and polystyrene cannot. Thermosetting binders are commercially available and have been used to solidify nuclear waste.^{27,28} Some thermosetting polymers have a limited shelf life because of premature polymerization, and are highly flammable.

5.4.4 Macroencapsulation

The RCRA technology based standard for treatment of radioactive lead solids is macroencapsulation, applying "surface coating materials such as polymeric organics (e.g. resins and plastics) or with a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media." (40 CFR 268.42) Any of the cements and binders discussed above could potentially be used to macroencapsulate bulk lead wastes, although the lower porosities and higher leach resistances of polymer materials would favor the organic binders. Also, a numerous macroencapsulation processes have been tested or used.

In one method,²⁹ waste is placed in a container which serves as a mold. Mixed epoxy resin is then poured into the mold to fill all void spaces and allowed to harden. The hardened monolith is then re-encapsulated by placing in a slightly larger mold and pouring additional epoxy around all sides. In another method,²² waste is placed in a basket that is centered in a container, with at least one inch space between the waste and all inner surfaces of the container. Molten polyethylene is then extruded around and over the waste. In a third method,²² a premanufactured polyethylene liner is placed into a container, the insert filled with waste and capped with molten polyethylene. In this method the top lip of the insert is heated to ensure a good bond with the poured cap.

Macroencapsulation is sometimes used in conjunction with microencapsulation. In one process,³⁰ the waste is first treated with lime, fly ash or Portland cement to produce a friable, dry solid. The resulting solids are ground and microencapsulated, typically with polybutadiene. The mass is then macroencapsulated by high density polyethylene. IC Technologies has tested a different multiple encapsulation method applied to a LANL waste stream containing lead and uranium.³¹ In this method, spherical pellets were prepared containing the waste and a water-activated polymer; then the pellets were treated with a thermosetting polymer, and finally the mass was encapsulated using either Portland cement or a thermosetting polymer.

Another possible option for disposal of the 1.3 million pounds of lead present in the SDA pits and trenches is macroencapsulation at an offsite facility. In late 1995, DOE contracted with Envirocare of Utah to treat and dispose of radioactive lead.³² DOE will supply 500,000 pounds of radioactively contaminated lead that Envirocare will treat by macroencapsulation, in order to demonstrate the effectiveness of the process.

5.4.5 Amalgamation

The amount of bulk mercury in the SDA pits and trenches is unknown, and is thought to be too small to justify sorting and separate treatment. Amalgamation is the RCRA-specified treatment standard for radioactively-contaminated mercury. When an excess of a metal such as copper or zinc is contacted with a waste containing mercury or mercury salts, mercury is reduced to the elemental form and forms an alloy with the metal. The alloy solidifies rapidly into a solid amalgam, which is more easily handled and less mobile than liquid mercury.

5.4.6 Tritium Stabilization

Because of tritium's short half-life of 12.3 years, stabilization of tritiated waste can be achieved by means not acceptable for long lived radionuclides. In 100 years, 99.6% of the tritium present in a waste will have decayed and in less than 250 years, 99.9999% will have decayed. Commonly used methods for tritium stabilization of aqueous wastes containing tritium include cementation, encapsulation, and absorption.

A high percentage of the tritium disposed of at the SDA is thought to be contained in beryllium blocks. If this waste is treated in a plasma melter, the tritium would be released, predominately in the form of tritiated water. If tritium has migrated into SDA soil, it will also be present in the form of tritiated water.

Solidification of aqueous wastes with Portland Cement has been the most popular method for tritium disposal.³³ However, to reduce the leachability of tritium from cement, other solidification methods have been developed or used including hydrothermal hot pressing using silicate powder,³³ cement composites and additives,³⁴⁻³⁸ and encapsulating waste with epoxy resin,^{35,36} water extendible polyester,^{35,36} high density polyethylene,³⁶ or bitumen.³⁷

Because of the importance of the waste container as a barrier against tritium release, one study recommended simply absorbing the liquid waste on sawdust.³⁶

It should be pointed out that it has not been established that stabilization of tritium waste will be needed in OU 7-13/14. While an estimated 1.2 million curies of tritium have been disposed at the SDA, it is not known how much remains in the waste or the soil surrounding the waste. BRA results will provide an indication of whether the risk due to tritium will mandate treatment for it. However, environmental regulations regarding tritium releases may also mandate capture and solidification.

5.4.7 C-14 Stabilization

An estimated 16,000 Ci of C-14 has been disposed at the SDA,³⁹ contained mostly in metal waste, but also wood, paper, trash, resins, construction materials, and core components. It is thus likely that some of the ¹⁴C-contaminated waste will be treated in the melter, converting the carbon to carbon dioxide. Whether the ¹⁴CO₂ in the offgas can be released to the atmosphere depends on dose calculations. The 16,000 Ci is equivalent to about 0.4% of the 4 million Ci of ¹⁴CO₂ present in the earth's atmosphere.⁴⁰

Technologies are well established to remove CO₂ from gas streams, being used in numerous industrial processes. Separation of ¹⁴CO₂ from nonradioactive CO₂ would be difficult, requiring cryogenic distillation or adaptation of other isotope separation processes, and would likely be more expensive than stabilizing the entire amount of CO₂.

Several processes have been developed to convert CO₂ into solid materials.⁴⁰⁻⁴⁶ In one process, carbon dioxide is reacted with Ca(OH)₂ to form calcium carbonate, which can then be packaged or further stabilized with cement or an organic binder. In a second process, CO₂ is removed from an offgas stream by contact with caustic to form sodium carbonate, which is reacted with Ca(OH)₂ in a second step to produce calcium carbonate and regenerate caustic. As an improvement over the calcium carbonate processes, the barium hydroxide hydrate process has been proposed and developed.⁴⁵ This process results in barium carbonate, which, because of the RCRA classification of barium as a hazardous material, would require disposal as a mixed waste. In another process, patented in Japan, CO₂ is absorbed into an organic solvent, which is then polymerized to form a solid waste.

While considerable development has gone into converting ¹⁴CO₂ into calcium or barium carbonate, the process has not been used in radioactive service, and additional development may be required before it could successfully be used in an OU 7-13/14 treatment system. In addition, solidification of carbon dioxide as carbonate may not offer adequate environmental protection. Kirkham and Lords⁴⁰ calculate that even if the carbonate grout is coated with a sealant, more than 85% of the original ¹⁴C would escape to the environment in 200 years.

5.5 Thermal Oxidation

Thermal oxidation technologies include different types of incinerators and catalytic oxidizers. Vitrification, sometimes considered a thermal oxidation technology, is included under stabilization. Some thermal processes involve two steps, such as pyrolysis, gasification or thermal desorption, followed by an oxidation unit. Oxidation technologies achieve volume reduction for combustible waste. However, since OU 7-13/14 COCs will likely be hazardous and radionuclide metals, thermal oxidation technologies are not retained as a technology.

5.6 Ex Situ Bioremediation

The two general methods of ex situ bioremediation are land treatment and bioreactors. Land treatment, also called land farming or prepared bed bioremediation, involves the excavation of the contaminated media, possible temporary storage, possible mixing of the contaminated soil/waste with other soils or materials, and then placement of the material on a prepared bed. The bed is typically layers of clay and a synthetic liner to prevent movement of fluid below the bed. Usually the placed material is regularly aerated, watered, and fertilized to increase degradation rates. The use of bioreactors, either lined pits with a drainage system and a system for feeding water, air and nutrients or one or more external vessels, allows for more control of the soil/waste environment.

The use of bioremediation for hazardous metals is very limited and for radionuclides is in the early stages of research and development. Since microorganisms can neither destroy the hazardous and radionuclide metals of OU 7-13/14 nor transform them into long-lived, nonleachable forms, bioremediation is eliminated from consideration as a technology for treating a major part of the soil or waste. However, as process steps in larger treatment processes, biotreatment has potential application. The following examples have been suggested or tested:

1. Degradation of citric acid used to leach Cd, Ni, Pb, Zn, Co, Sr, Th, and U from solid wastes^{47,48}
2. Removal of heavy metals from wastewaters^{49,50}
3. Bioleaching or mobilization of heavy metals from soil, including radionuclides⁵¹⁻⁵⁴
4. Stabilization of Pu in soil following treatment by chemical leach.⁵⁵

5.7 Storage

Storage alternatives are not covered in this EDF, but will be included as part of alternative 5.

5.8 Disposal

Disposal alternatives include onsite disposal at various facilities, disposal at WIPP and disposal at offsite facilities. Disposal alternatives were not developed or information collected for this EDF. Onsite and offsite disposal options will be examined for non-TRU waste. For TRU waste, WIPP is assumed to be the only offsite disposal option.

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ANSWERS TO REVIEW QUESTIONS & COMMENTS ON ER-WAG7-92

1. Regarding access limitations, if markers don't work, what does? What do we evaluate in the FS?

We evaluated markers as the best available technology. This alternative, Institutional Controls, fails in many of the evaluation criteria.

2. Are we going to evaluate bottoms up ISV in the FS?

I suggest that in the technical memo that evaluates process options and technologies, we discuss vitrification as:

1. Conventional ISV (top-down, without pretreatment)
2. Top-down, with pretreatment
3. Bottoms-up
4. Staged cell.

"Conventional" ISV can be screened out for a variety of reasons, including insufficient characterization data for OU 7-13/14, pit depths beyond the ISV limit, potential for fires, and potential for VOC migration, and the poor performance in waste areas containing large metal objects, waste areas high in metal or combustibles, sealed drums of organic liquid, or gas cylinders. The pretreatment and bottoms-up approaches could be left in but not evaluated or screened out because each has issues. Even with pretreatment, there is the depth issue, and problems because of waste content. Also there is little data demonstrating the effectiveness of pretreatment. The bottoms-up approach solves the depth issue but not the others, and as well has little data to demonstrate effectiveness. Thus the only alternative left is the stage cell approach. Although much more expensive than the other options because it included retrieval, it is the only implementable one.

3. Are we screening out a) phase separation, b) chemical decontamination, or c) amalgamation?

No. Any treatment process will likely have multiple phase separation steps. Those in the Pit 9 process include the TEA/water liquid/liquid separator, the V-sep filters, the carbon beds for mercury, and HEPA filters. Any retrieval alternative will need at least one decontamination process. Because so many decon methods are commercially available and relatively low cost, we'll select one or two as representative. I don't think we have a basis to screen amalgamation, as it's the RCRA-specified treatment standard for rad-contaminated elemental mercury, but, following the Pit 9 treatment process and because of lack of information on whether or how much elemental mercury waste is buried, we will not include it as a cost element in the detailed evaluation.

4. What information is being gathered for stabilization of tritium, C-14, bulk lead, and mercury?

Tritium: See Section 5.4.6

C-14: See Section 5.4.7

Mercury: See Sections 5.4.5 and 5.4.2-5.4.4

Lead: See Sections 5.4.4

5. Will we evaluate the various polymer stabilization processes in the FS? What is our representative process?

No, I didn't intend on doing any further evaluation of polymer stabilization processes than is in the EDF, unless C-14 is a COC. Our selection of representative stabilization processes will depend on the details of what the final ex-situ treatment alternative is. If it is basically the Pit 9 system, then the stabilization process for the scrubber blowdown, like Pit 9, is an inorganic process. If we obtain data from the LDRD or other sources that that process won't work or should be modified, we'll select a different process as representative. If C-14 is a COC, we will need to select a process to stabilize it, and to do so, further evaluation will be needed. Polymer processes may be a good candidate for C-14 stabilization.

6. Disposal of lead: Is bulk lead likely to be a COC?

No, I have not seen anything that would indicate it is likely to be a COC. However, if contaminated lead waste is assumed to present in OU 7-13/14, I doubt we can exclude it from the list of contaminants for which delisting levels will be established (although Pit 9 did exclude it). The Doug Burns letter does show all lead in Pit 17, which if true, and if Pit 17 is not retrieved, would make treatment for it unnecessary.